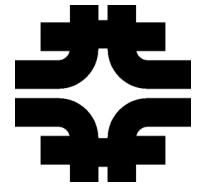


Neutrino Futures

Gina Rameika

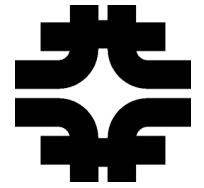
Particle Physics Division

Neutrino Department



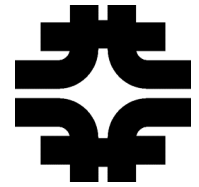
Outline

- Introduction
 - θ_{13} and Beyond
- Future US Long Baseline Study
 - Beamline Options
 - Detector Options
- Small Intermediate Efforts
 - Detector R&D
 - New Experiments
- The PPD Neutrino Department



The Current Program

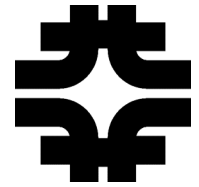
- MINOS, MiniBooNE/SciBooNE – separate breakout talks
- NOvA, MINERvA
 - Many separate reviews (CD process)
 - Overview in plenary
- Detector Tests
- Long Range Planning



θ_{13} Program

- Phase I (~ 2009 – ~ 2013):
 - World wide effort to measure θ_{13}
 - Reactor experiments :
 - Double Chooz and Daya Bay
 - Accelerator long baseline :
 - JPARC to SuperK (T2K) and NOvA
 - Phase I experiments will determine if $\sin^2 2\theta_{13} > 0.05$ very quickly
 - If $\sin^2 2\theta_{13} > 0.05$ NOvA may be able to determine the mass hierarchy (depends on the value of δ_{CP})
 - If $0.02 < \sin^2 2\theta_{13} < 0.05$ it will take longer to determine this;
 - determining the mass hierarchy will be difficult and sensitivity to CP is ultimately achievable but even more challenging (I.e. Phase II)

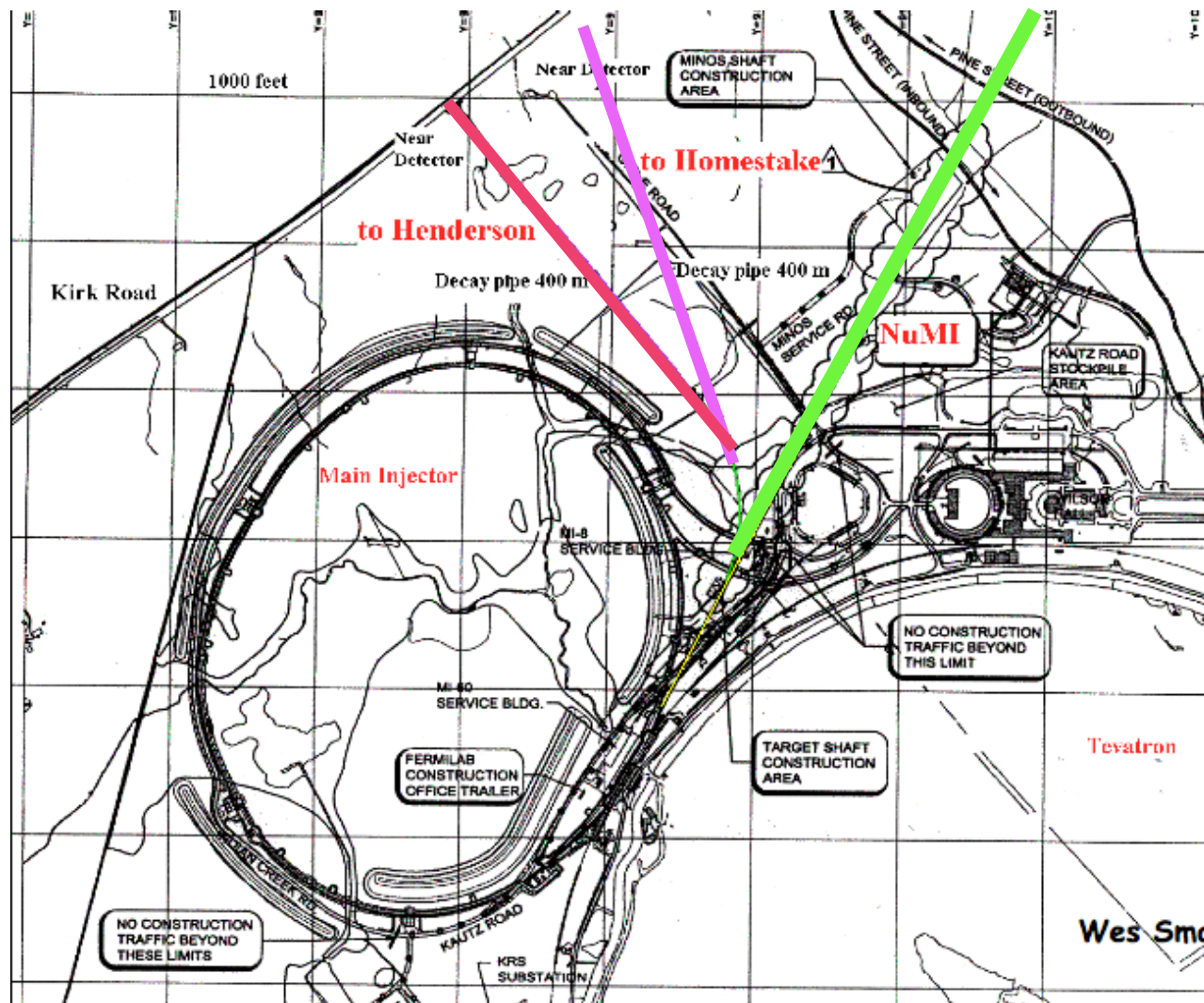
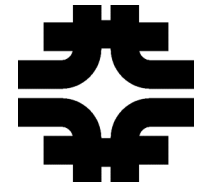
The Future US Long Baseline Study



The charge to the Study participants (Montgomery/Dawson)

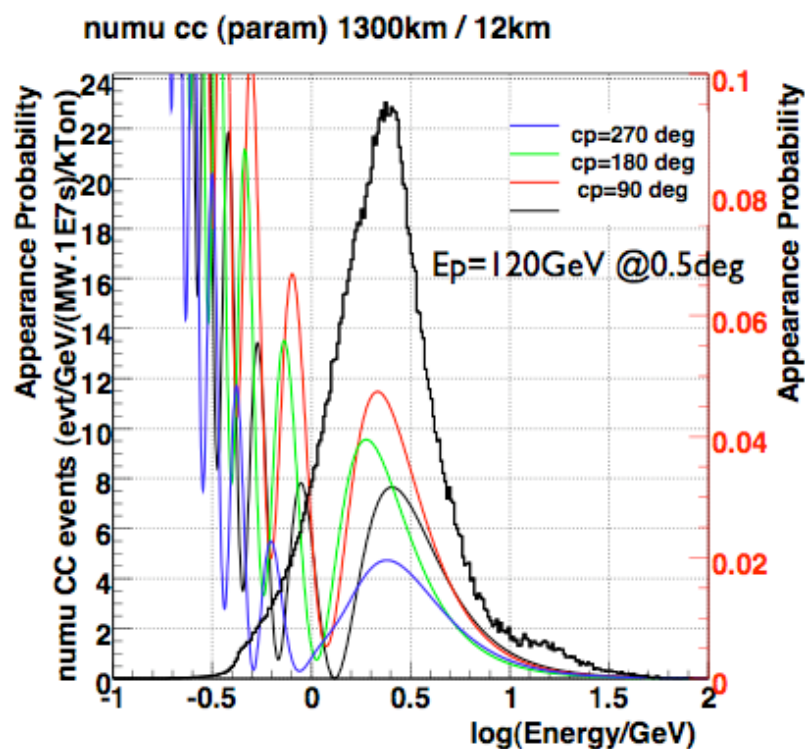
- Compare the neutrino oscillation physics potential of :
 - Broadband beam to a DUSEL site
 - Next Generation Off-Axis options
 - Liquid Argon Detector
 - At DUSEL or
 - As a second NOvA detector
 - Proton options
 - ~ 1 MW from existing accelerator complex
 - 1 – 2 MW
 - Proton Driver (~ 2 MW)
-

Beamline Options



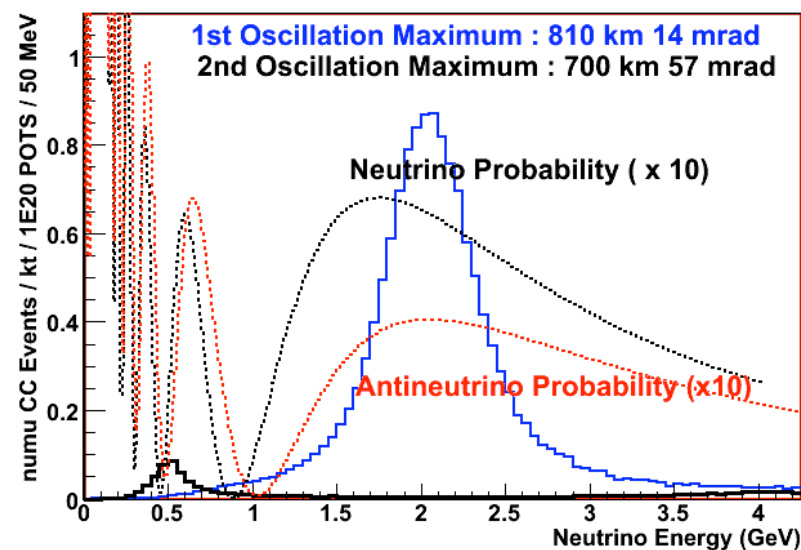


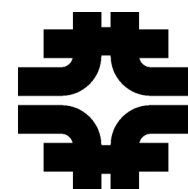
Neutrino Beam Options



•NEW -
Wide Band Beam

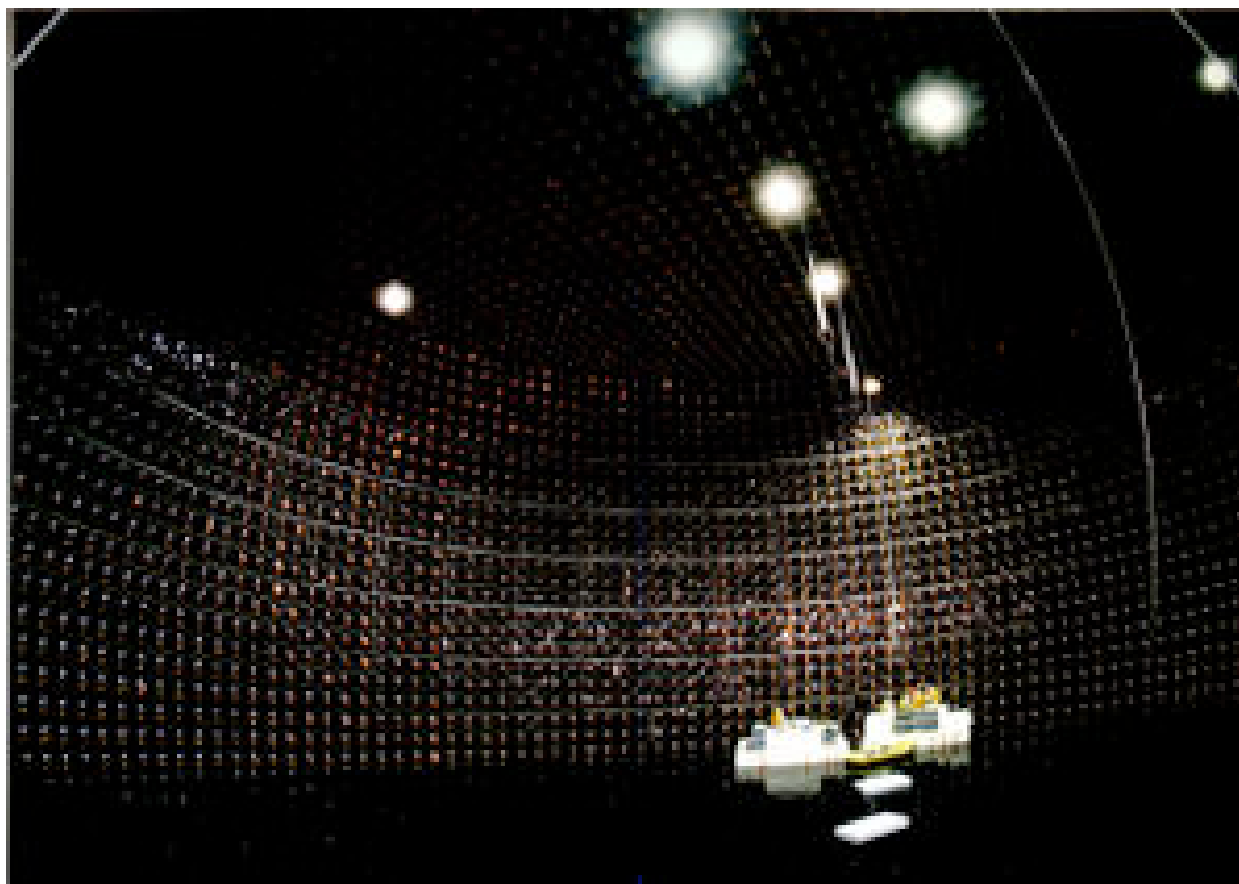
•NuMI - Off-Axis
(narrow band)

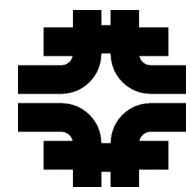




Detector Options

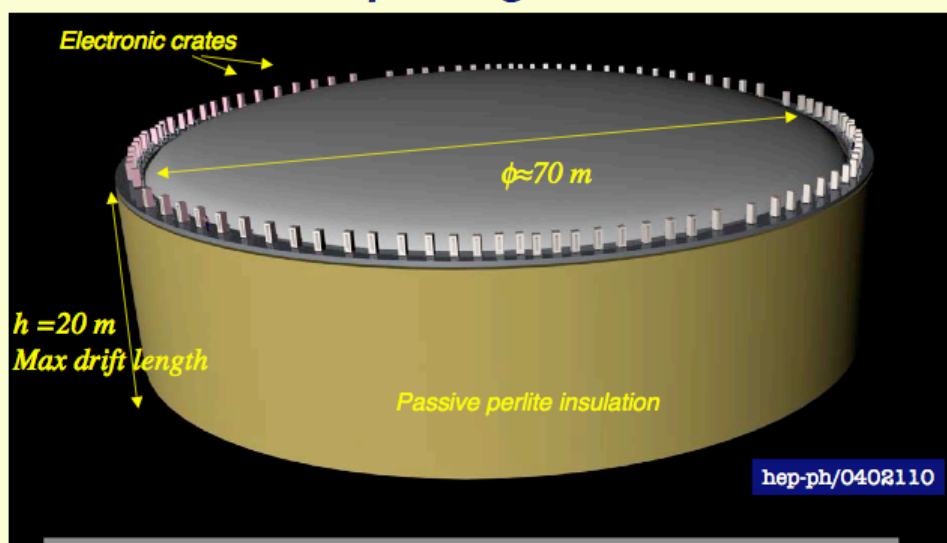
- **Large** Water Cerenkov ($\sim 6 - 10 \times$ Super-K)



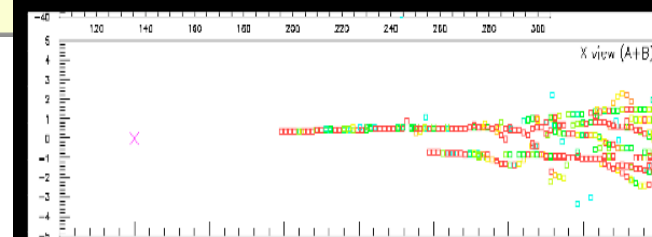
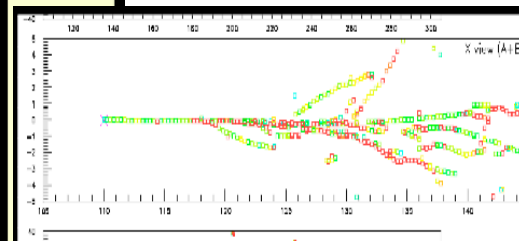


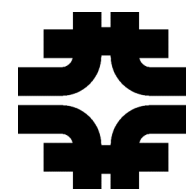
Or • Large Liquid Argon (~ 100 ktons ? !)

A 100 kton liquid Argon TPC detector

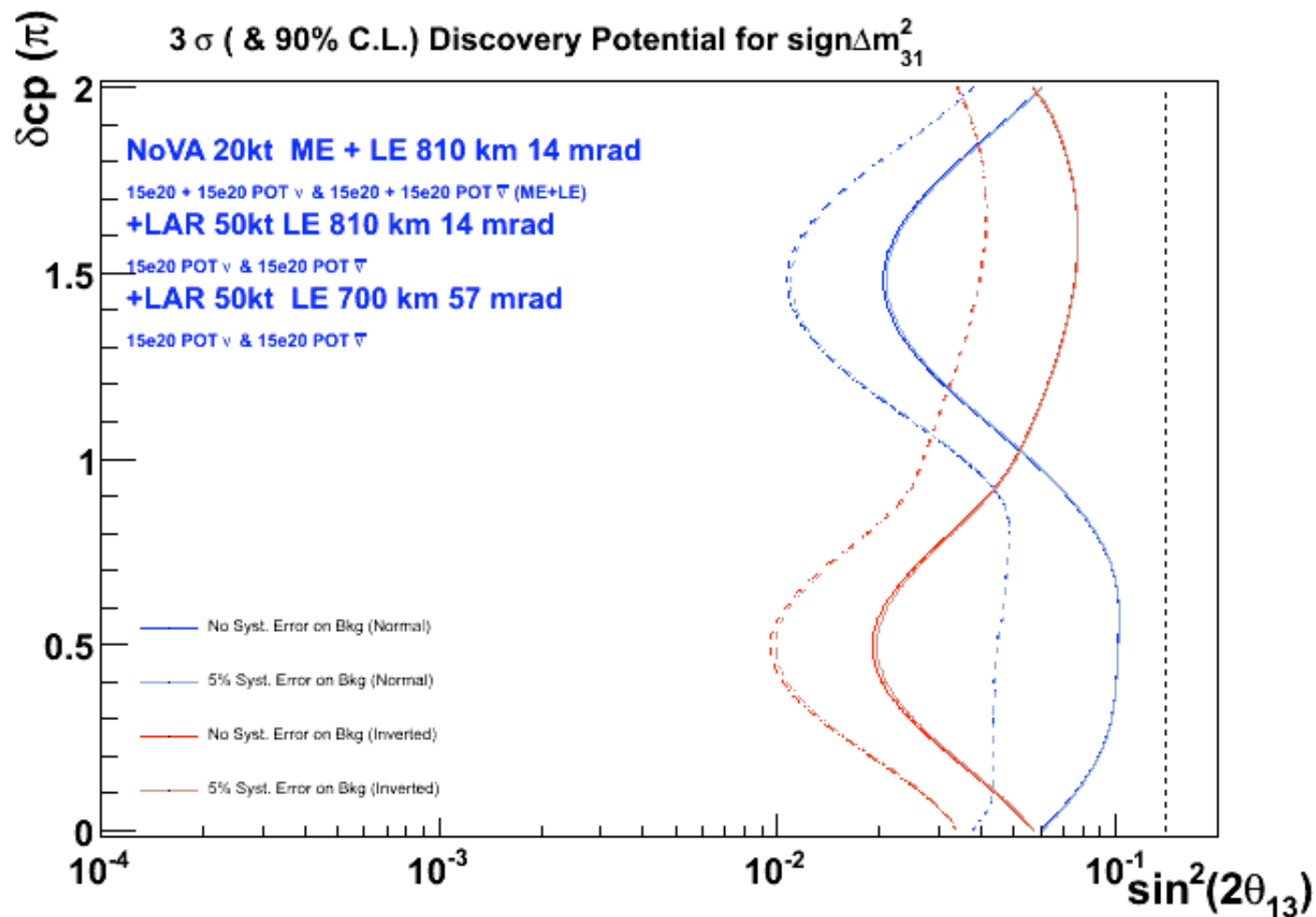


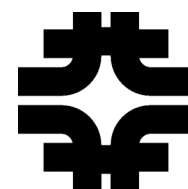
Single module cryo-tanker based on industrial LNG technology



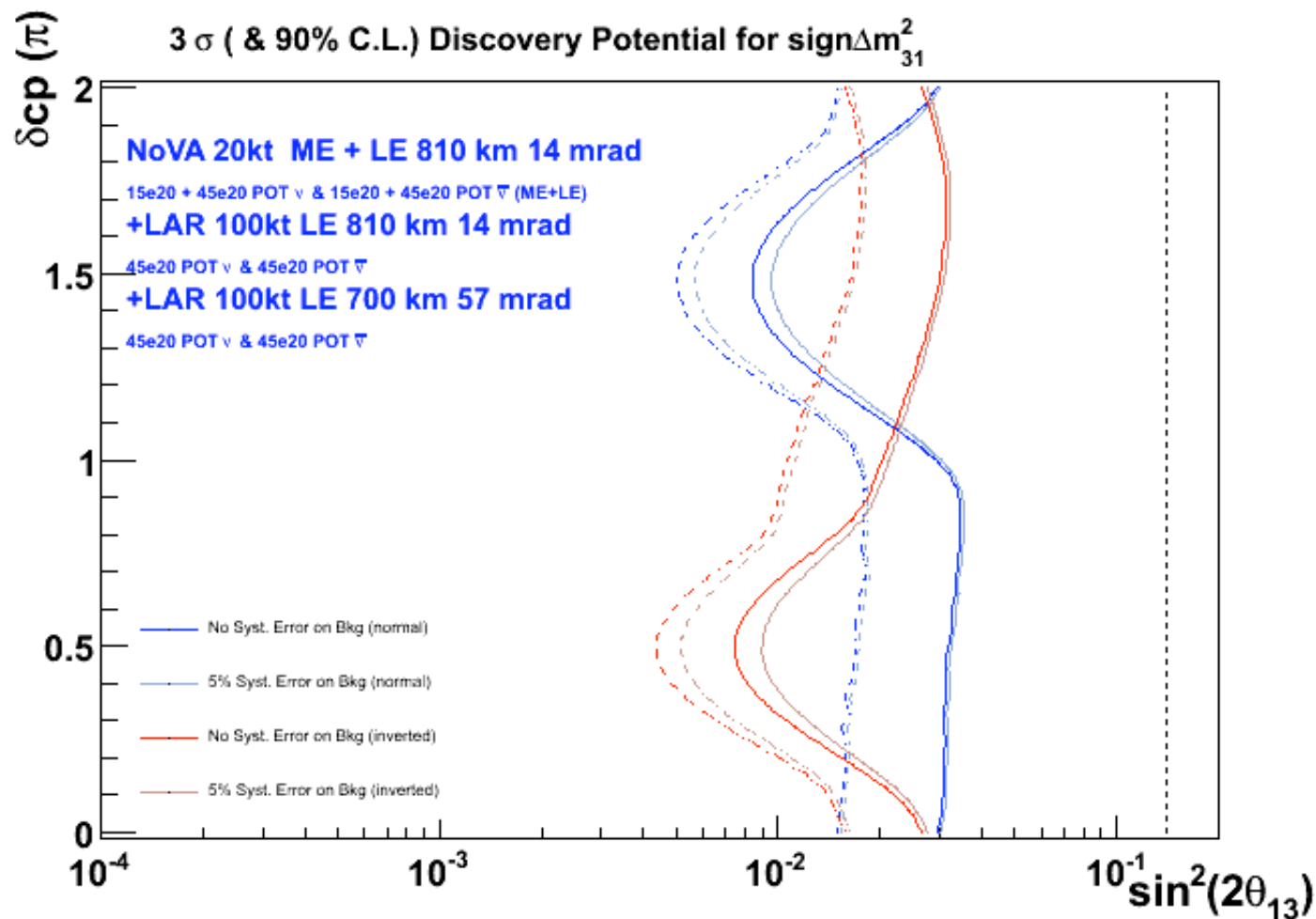


Sensitivity Plots ...



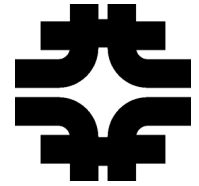


... for a variety of scenarios



See full report ...

Fermilab-0801-AD-E
BNL-77973-2007-IR



Report of the US long baseline neutrino experiment study

V. Barger,¹ M. Bishai,² D. Bogert,³ C. Bromberg,⁴ A. Curioni,⁵ M. Dierckxsens,²
M. Diwan,² F. Dufour,⁶ D. Finley,³ B. T. Fleming,⁵ J. Gallardo,² D. Gerstle,⁵ J. Heim,²
P. Huber,¹ H. Jostlein,³ C. K. Jung,⁷ S. Kahn,² E. Kearns,⁶ H. Kirk,² T. Kirk,⁸ K. Lande,⁹
C. Laughton,³ W. Y. Lee,¹⁰ K. Lesko,¹⁰ C. Lewis,¹¹ P. Litchfield,¹² A. K. Mann,⁹
A. Marchionni,³ W. Marciano,² D. Marfatia,¹³ A. D. Marino,³ M. Marshak,¹² S. Menary,¹⁴
K. McDonald,¹⁵ M. Messier,¹⁶ W. Pariseau,¹⁷ Z. Parsa,² S. Pordes,³ R. Potenza,¹⁸ R. Rameika,³
N. Saoulidou,³ N. Simos,² R. Van Berg,⁹ B. Viren,² W.T. Weng,² K. Whisnant,¹⁹ R. Wilson,²⁰
W. Winter,²¹ C. Yanagisawa,⁷ F. Yumiceva,²² E. D. Zimmerman,⁸ and R. Zwaska³

¹*Department of Physics, University of Wisconsin, Madison, WI 53706, USA*

²*Physics Department, Brookhaven National Laboratory, Upton, NY 11973, USA*

³*Fermi National Accelerator Laboratory, Batavia, IL 60510, USA*

⁴*Department of Physics and Astronomy,*

Michigan State University, East Lansing, MI 48824, USA

⁵*Department of Physics, Yale University, New Haven, CT 06520, USA*

⁶*Department of Physics, Boston University, Boston, MA 02215, USA*

⁷*Stony Brook University, Department of Physics and Astronomy, Stony Brook, NY 11794, USA*

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⁹*Department of Physics and Astronomy,*

University of Pennsylvania, Philadelphia, PA 19104, USA

¹⁰*Lawrence Berkeley National Laboratory,*

Physics Division, Berkeley, CA 94720, USA

¹¹*Department of Physics, Columbia University, New York, NY 10027, USA*

¹²*School of Physics and Astronomy, University of Minnesota, Minneapolis, MN 55455, USA*

¹³*Department of Physics and Astronomy,*

University of Kansas, Lawrence, KS 66045, USA

¹⁴*Department of Physics and Astronomy,*

York University, Toronto, Ontario M3J1P3, Canada

¹⁵*Department of Physics, Princeton University, Princeton, NJ 08544, USA*

¹⁶*Department of Physics, Indiana University, Bloomington, IN 47405, USA*

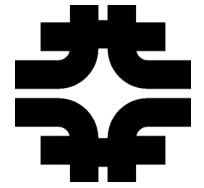
¹⁷*Department of Mining Engineering,*

University of Utah, Salt Lake City, UT 84112, USA

March 2006 -
May 2007

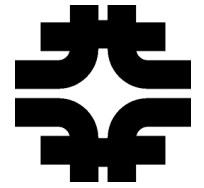
arXiv:0705.4396
(May 2007)

September 26, 2007



The NuSAG Report (July 2007)

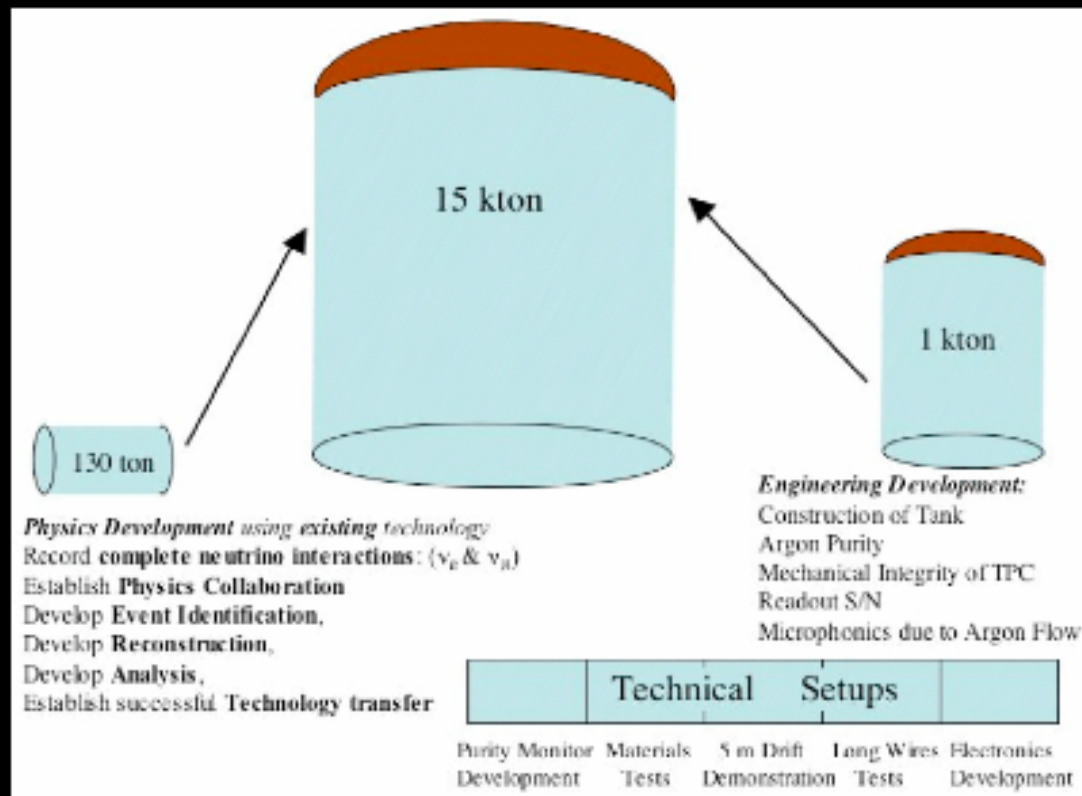
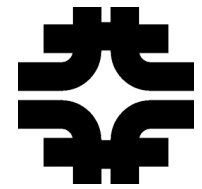
- Simultaneous with the FNAL/BNL Study, NuSAG was also charged to explore the options for future US long baseline experiments...
 - Focused on experiments to determine the neutrino mass hierarchy and δ_{CP}
 - Knowledge that $\sin^2 2\theta_{13} > 0.01$ is REQUIRED before considering future options that use conventional neutrino beams (~ 1 MW beam power)
 - 1st results around 2012
 - Main Conclusion : in the interim, focus on R&D towards intense beams and large detectors

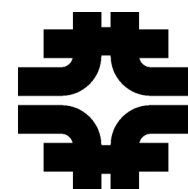


In particular....

Recommendation 4. A phased R&D program with milestones and using a technology suitable. For a 50-100 kton detector is recommended for the liquid detector option. Upon completion of the existing R&D project to achieve purity sufficient for long drift times, to design low noise electronics , and to qualify materials, construction of a test module that could be exposed to a neutrino beam is recommended.

June 2005 R&D “proposal” to NuSAG



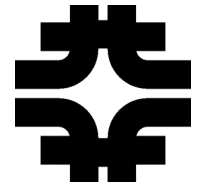


LAr R&D at Fermilab



- Purity
 - Drift distance
 - Purity Monitoring
- Electronics
 - Signal/noise
- TPC construction techniques

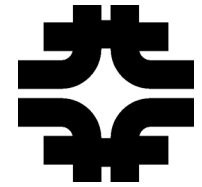
Resource expenditures : a few FTE's, ~\$300K M&S per year → slow progress



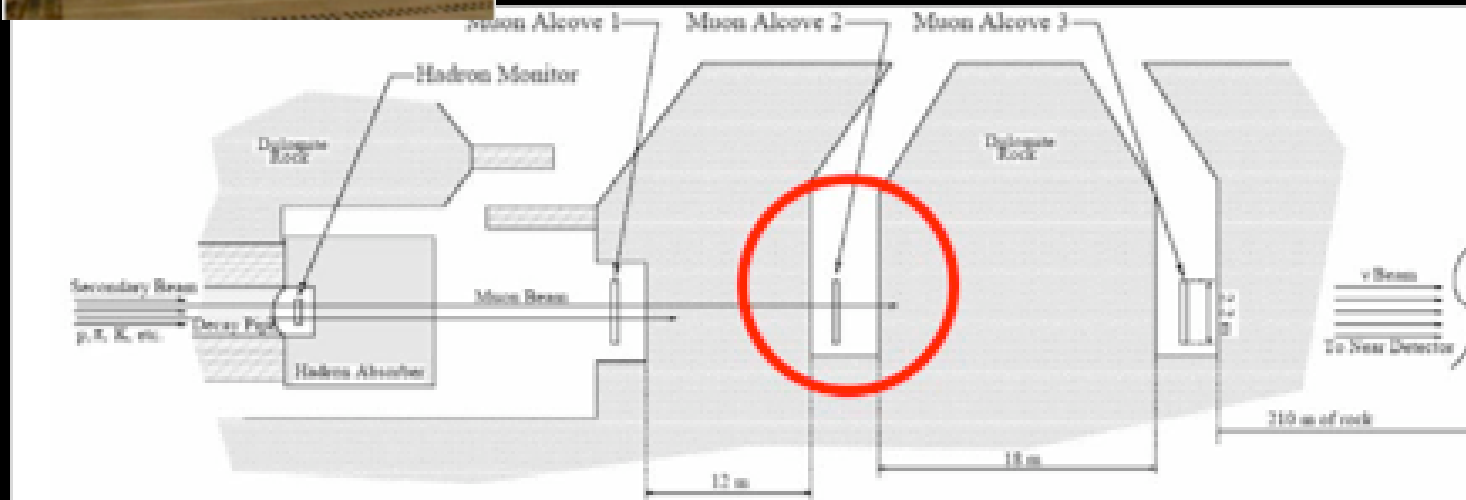
Small, Interim Initiatives

- “Tests”
 - PEANUT (T-952)
 - ArgoNut (T-962)
 - T2K Beam Monitors (T-968)
- Proposals/EOIs → New Experiments

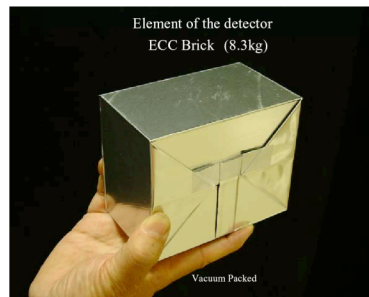
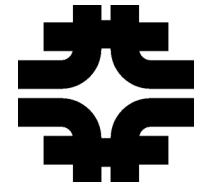
T-968



Test of T2K MUMON beam monitors
in NuMI muon alcove ;
muon rate : $10^6/\text{cm}/\text{spill}$



PEANUT



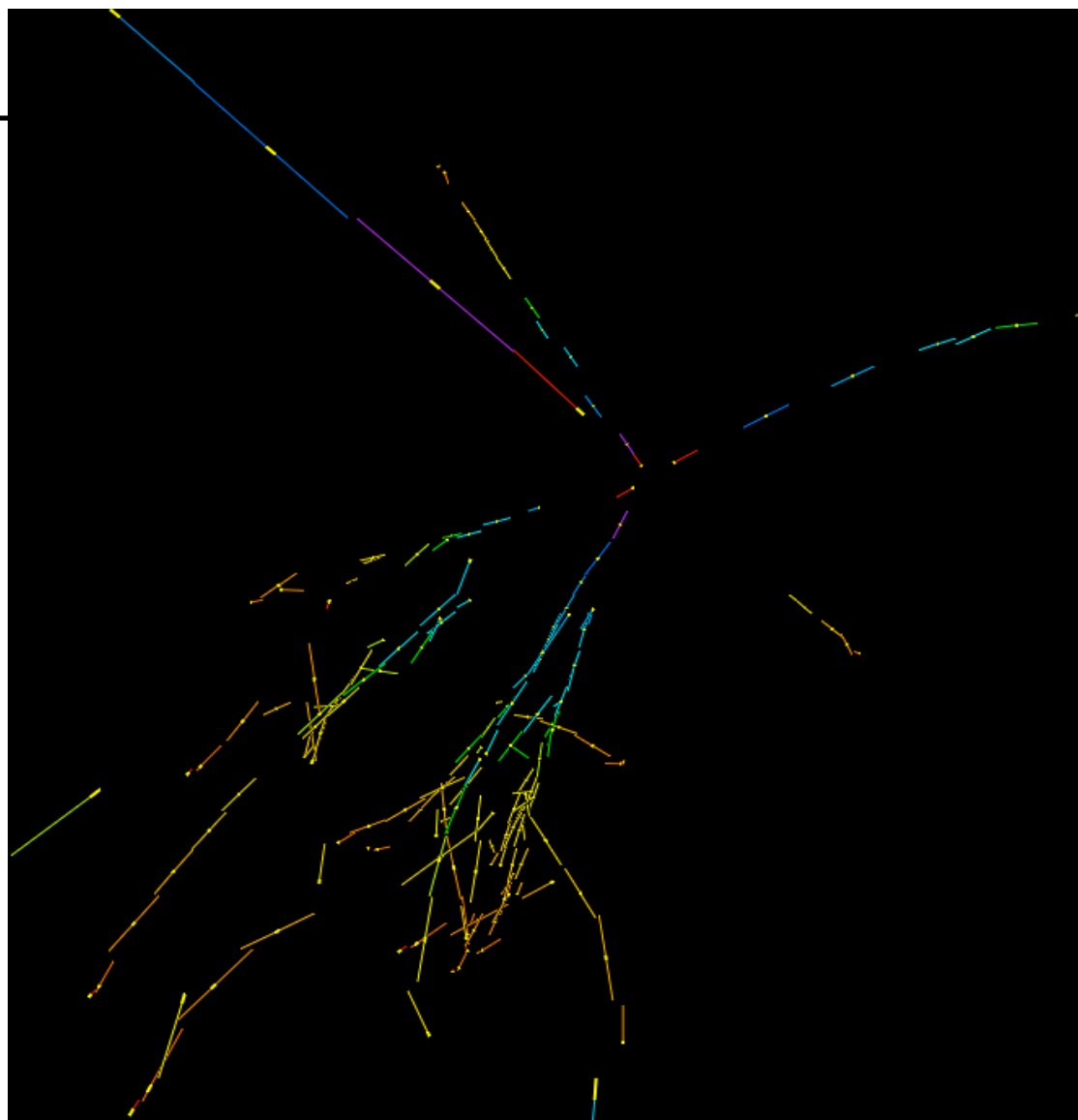
NuMI beam exposure of OPERA emulsion bricks ; October 2005 - February 2006 June - July 2007

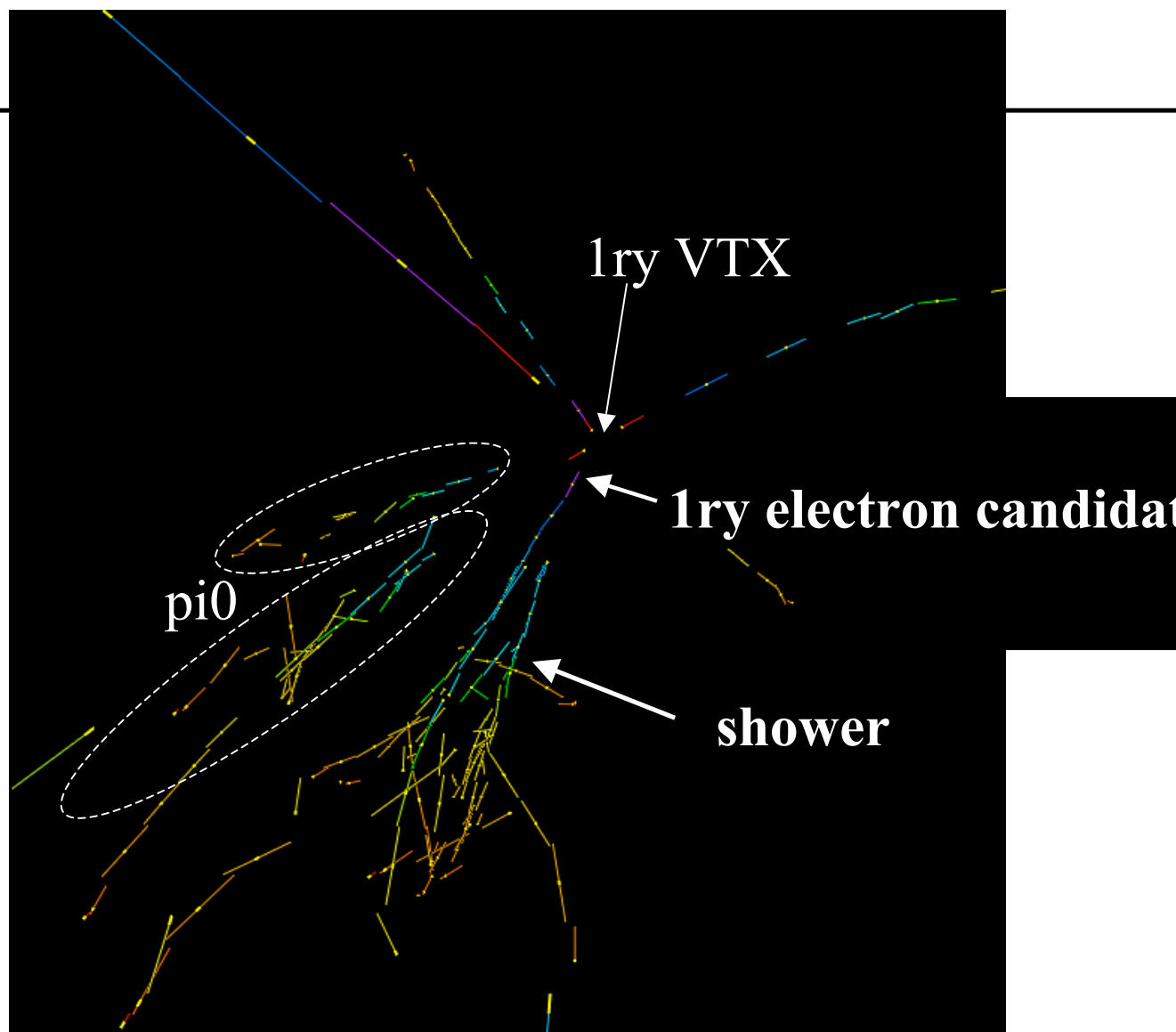
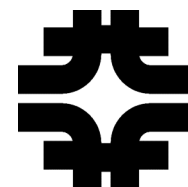


September 26, 2007

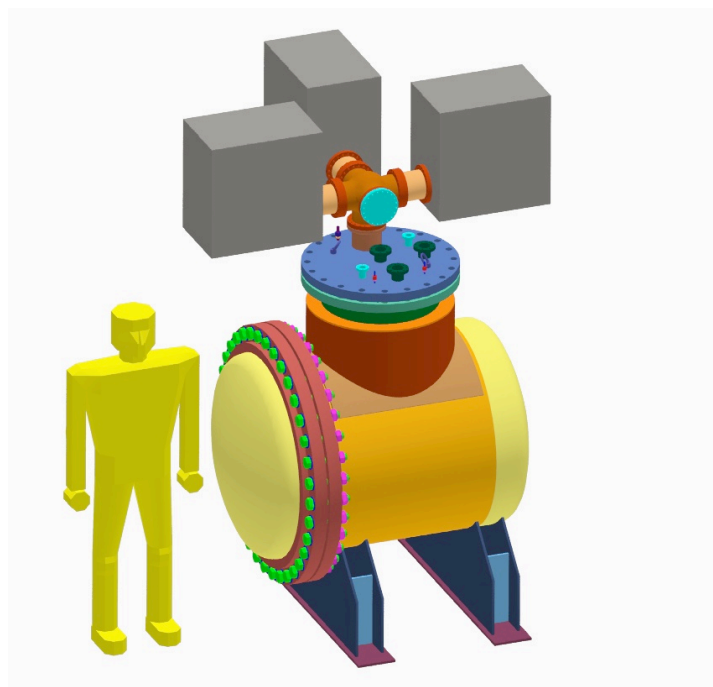
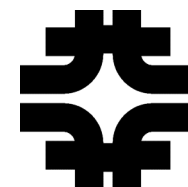
2007 Annual Program Review - R. Rameika

19



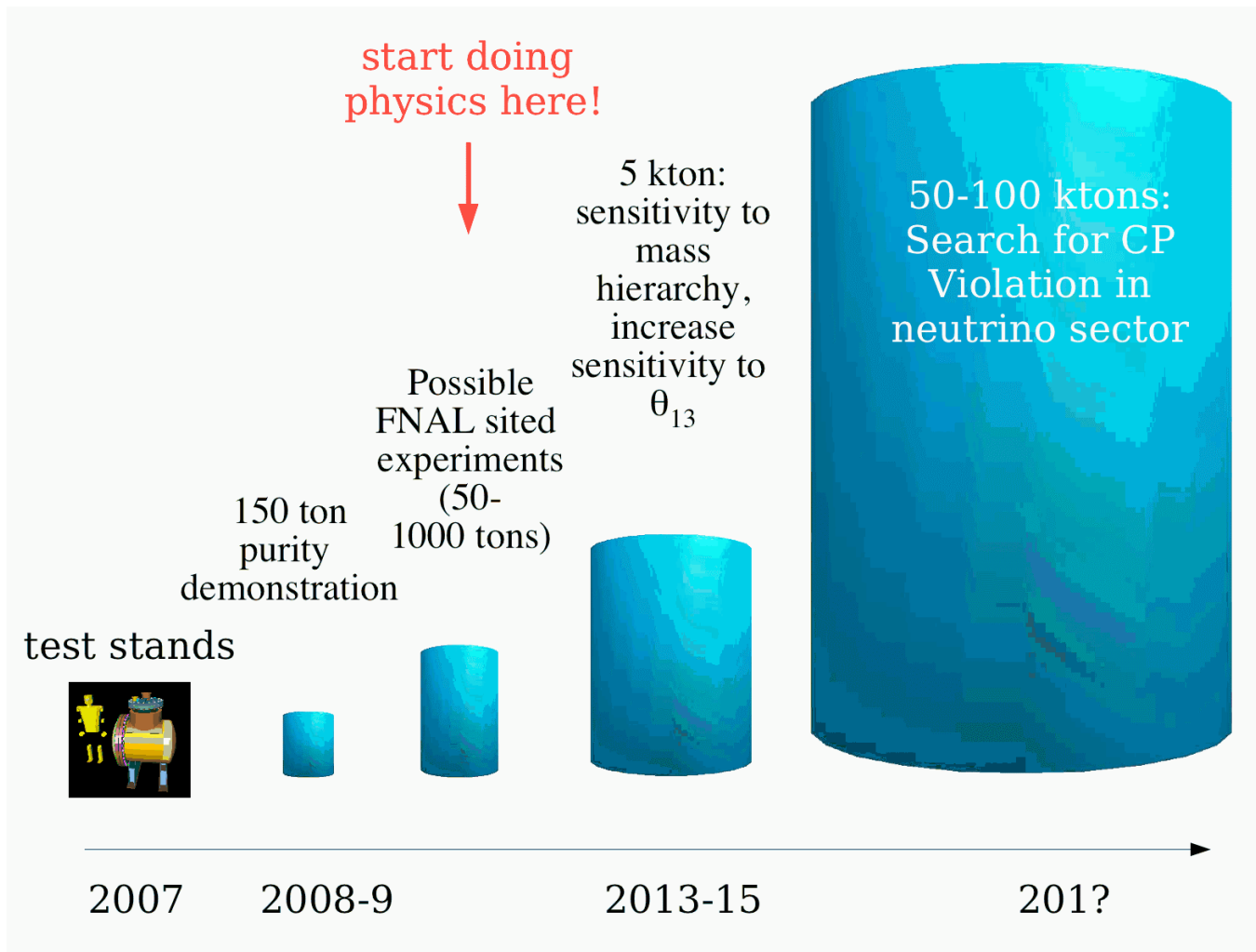
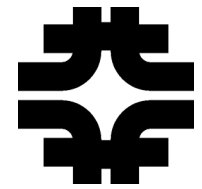


Detector R&D - LArTPC



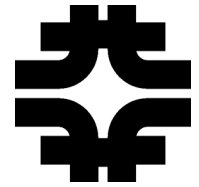
Idea is to install in the NuMI Hall;
Close to MINOS, if doesn't interfere
with Minerva

Vision for evolution of the R&D “program”



Fermilab Steering Group

Spring/Summer 2007



One Page Proposals from the community

[6GeV ILC Test Linac - Giorgio Apollinari and Bob Webber \(May 7, 2007\)](#)

[LAr TPC in FNAL's Neutrino Beams - David Finley \(May 29, 2007\)](#)

[Precision Neutrino Scattering at Tevatron - Janet Conrad and Peter Fisher \(May 29, 2007\)](#)

[Very Large Cherenkov Detector - Milind Diwan et al \(June 5, 2007\)](#)

[From Tevatron to Muon Storage Ring - Terry Goldman \(June 6, 2007\)](#)

[Antimatter Gravity Experiment - Thomas Phillips \(June 7, 2007\)](#)

[Neutrino Oscillation with high energy/intensity beam - Henryk Piekarczyk \(June 10, 2007\)](#)

[Space-Time Ripples Study - Nikolai Andreev \(June 11, 2007\)](#)

[Fixed Target Charm Expt - Jeff Appel and Alan Schwartz \(June 11, 2007\)](#)

[Stopped Pion Neutrino Source - Kate Scholberg \(June 11, 2007\)](#)

[UNO Experiment - Chang Kee Jung \(June 11, 2007\)](#)

[n-nbar Transition Search at DUSEL - Yuri Kamyshev \(June 11, 2007\)](#)

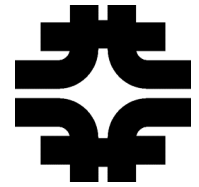
[8GeV cw Superconducting Linac - Ankenbrandt et al. \(June 12, 2007\)](#)

[Neutrino Expt with 5kton LAr TPC - Fleming and Rameika \(June 12, 2007\)](#)

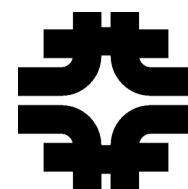
[MicroBooNE - Fleming and Willis \(June 12, 2007\)](#)

[\$\delta a_\mu\$ - Rex Tayloe \(June 14, 2007\) \(June 14, 2007\)](#)

The PPD Neutrino Department



- Mission -
 - to support Neutrino Physicists (both Fermilab staff and visiting collaborators)
 - Administrative needs, i.e. offices, travel
 - Desktop Computer support
 - To help shape the Laboratory's future program by doing experiments, producing physics results and planning future experiments
- Formed in Spring 2005
 - ~ 20 FNAL Staff
 - MINOS, MiniBooNE, SciBooNE, Minerva, NOvA + future experiments and detector tests
- Activities
 - Neutrino Summer School
 - Journal Club
 - Neutrino Discussion Group



Summary & Conclusion

- Fermilab neutrino program is active and diverse.
- Operating experiments MINOS and MiniBooNE and SciBooNE are collecting data and producing exciting results and publications.
- The Minerva and NOvA projects are progressing through reviews and will hopefully move from R&D to construction shortly.
- Our existing facilities are being used to support a variety of R&D test activities for both the Fermilab and world wide neutrino program.
- Planning for a θ_{13} Phase II experiment is an important part of our neutrino program
 - R&D for intense beams and large detectors is essential